OUTWARD AND INWARD TKACHEVS ON UNEVEN PARALLEL BARS

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The purpose of this study was to determine whether changing the bar spacing has influenced the nature of Tkachevs performed on uneven bars. Video recordings of straddle Tkachevs performed outwards (n=5) and inwards (n=5) along with a piked Tkachev (n=1) also performed inwards, were collected from the 2000 Sydney Olympic Games. A large increase in angular momentum was observed (74%) in the straddle facing inward over the outward facing Tkachevs. Analysis of the gymnasts' flight profiles also showed that when adopting the newer inward style, the gymnasts had greater bar clearance as a result of a steeper trajectory. The development of the newer inward style has facilitated the execution of more adaptations of the Tkachev.

KEY WORDS: women's artistic gymnastics, angular momentum.

INTRODUCTION:

Release and re-grasp skills on the uneven parallel bars form a major component of elite gymnastics routines. The Tkachev is the most common of the release and re-grasp skills in female gymnastics (Holvoet *et al.,* 2002). Historically this skill has been performed with the gymnast facing outwards (O) and travelling towards the low bar whilst clearing the high bar. Changes in the rules governing the dimensions of this apparatus have enabled females to longswing the opposite way, facing inwards (I) and travelling away from the low bar when performing the Tkachev flight element. Consequently gymnasts now have the option of performing the Tkachev in either direction (FIG, 2006). Altering the direction in which gymnasts swing around the bar has implications for technique during the preceding longswing. The technique of the longswing has been shown to be related to the successful performance of the Tkachev (Arampatzis and Brüggemann, 2001). Irwin and Kerwin (2006) noted that 70% of the work done in the longswing, in men's gymnastics, occurs during the functional phases of the hips and shoulders; defined by maximum shoulder flexion to extension and hips extension to flexion as the gymnast passes the lower vertical (Irwin and Kerwin, 2005). The lower bar poses a physical restriction to the ideal "pendulum" style longswing detailed by Yeadon and Hiley (2000). The female gymnasts must alter the longswing technique to avoid the lower bar whilst still developing the angular momentum and release characteristics required to perform the skill. Avoidance of the lower bar can be achieved by either straddling the legs or, more commonly, by flexing the hips (Witten *et al*., 1996; Hiley and Yeadon, 2005). Reversing the direction of the longswing removes the restriction imposed by the low bar on the downswing phase but introduces a potential change in technique on the upswing. The implications of changing direction in the longswing preceding the Tkachev present a challenge to the gymnast and coach. Therefore the purpose of this study was to quantify the biomechanical differences during the preceding longswing and flight of the Tkachev when facing outwards and inwards to assess the influence of the bar spacing rule change on the execution of this complex skill.

METHOD:

Data collection: The data for this study were collected during the 2000 Sydney Olympic Games. Two camcorders (Sony Digital Handycam DCR VX1000E, Japan) were positioned approximately 35 m away from and 8 m above the uneven parallel bars. The optical axes of the cameras intersected at approximately 66˚ over the centre of the bars. Both cameras captured the images at 50 Hz with a shutter speed of 1/600 s. Prior to the performances, images were recorded of a three dimensional calibration matrix comprising 20 known points encompassing the apparatus (3m x 4.5m x 4m). During the competition, images of straddle

Tkachevs performed outwards (n=5) and inwards (n=5) from the apparatus, together with one performance of piked Tkachev inwards, were recorded.

Data processing: Calibration and movement images were digitised from each cameras view using the TARGET high resolution motion analysis system (Kerwin, 1995). The movement data comprised images for the preceding longswing, the release and flight phase of the Tkachev. In each sequence the centre of the high bar and the gymnast's head, her right and left wrists, elbows, shoulders, hips, knees, ankles, and toes were digitised. An 11 parameter direct linear transformation (Abdel-Aziz and Karara, 1971) was implemented to calibrate the cameras and reconstruct the coordinate data. The inertia parameters of each segment were customised using Yeadon's inertia model (1990), limb lengths determined from the video analyses and each gymnast's height and mass.

Data analysis: The reconstructed 3D coordinate data were processed with the 'ksmooth' function (MatchCad[13]™, Adept Scientific, UK) with the parameter 's' set to 0.10. This routine has similar characteristics to a Butterworth low-pass digital filter with the cut-off frequency set to 4.5 Hz, (Kerwin and Irwin, 2006). The left and right sides of the body were averaged to produce a four segment planar representation of the gymnast, (arm, trunk, thigh and shank). The instants of release and re-grasp were defined by quantifying 'grip radius' as the linear separation between the 'mid-wrists' and the centre of the high bar. Release was considered to have occurred once the grip radius exceeded the maximum value obtained during the preceding longswing. Re-grasp occurred as soon as the grip radius returned to within the previously established maximum. The horizontal and vertical motion of the gymnast's mass centre (CM) during flight was fitted with linear and quadratic functions respectively. Regression values were predicted from the corresponding functions to define the flight phase, enabling flight time, and CM displacements and velocities at release and re-grasp to be obtained. In addition, from the flight characteristics of the CM, maximum flight height (Sz_{max}), horizontal position of CM relative to the bar at release (Sy_{zmax}) and height of the CM as the gymnast passed over the high bar ($Sz_{y=0}$) were determined. Angular momentum of each segment about its mass centre ($L_s = I_s \cdot \omega_s$) and of each segment about the whole body mass centre ($L_o = m \cdot \Omega \cdot r^2$) were summed over the four segments to obtain angular momentum of the gymnast about her body mass centre (L_c), ($L_c = L_s + L_o$). To facilitate direct comparisons between gymnasts of varying sizes, angular momentum values were normalised (L_n) by dividing L_c by her moment of inertia (I_{ss}) in a theoretical straight position and also by 2π to produce units of straight somersaults per second (SS/s).

RESULTS & DISCUSSION:

Release characteristics for the outward facing Tkachev (O) were lower than those for the newer inward facing style (I), (Table 1). Vertical release velocity (Vz) and release angle (θ_{cm}) were higher indicating that the gymnasts had generated more rotation in the preceding longswing up to release in the newer inward facing style of Tkachev. This is endorsed by the angular momentum profiles. It is interesting to note that the gymnasts performing the newer style were slightly larger (41.29 kg, 1.52 m) than those performing the older style skill (37.20 kg, 1.46 m). By using the normalisation procedure, these size differences were factored out leaving the release angular momentum for the newer technique 52% higher than for the original one. It is clear that either the lack of any obstruction by the low bar on the preceding downswing, or the actions performed by the gymnasts in the functional phases helped to create the additional angular momentum in the newer style. Comparing the data with that reported by Arampatzis & Brüggemann (2001), the current release values are generally lower. However, between these two studies the rule change was implemented enabling the bars to be separated to the new maximum limits. This has resulted in slightly different techniques being adopted. The newer style allowed gymnasts to develop 74% more angular momentum at release before the straddle Tkachevs. Greater angular momentum at release might be expected for the piked Tkachev as the segment orientation of the gymnast during flight increases the moment of inertia around the gymnast's mass centre. The observed L_n

values (Table 1) show that after normalisation, angular momentum at release was surprisingly similar to that for the outward straddle. The more extended body shape (I_{cm} ~8 compared to ~5.5 kg·m^2 for the straddle) at the time when the gymnast is aiming to reverse the direction of her angular momentum vector would act to limit the release value. The slightly lower vertical velocity appears to have been compensated by a higher release angle and hence identical vertical bar clearance to the corresponding straddle Tkatchev. Greater horizontal velocity and flight time in the piked Tkatchev have also provided the increased range needed to clear the high bar in a piked position.

Table 1 Release and flight parameters for the women's straddle Tkachev facing outwards and inwards relative to the apparatus (mean [±sd]), and for one piked Tkachev (inwards).

	$Time_{flight}$ (s)	θ_{cm} (º)	Sz (m)	Sy_{zmax} (m)	Sz_{max} (m)	$Sz_{y=0}$ (m)
Straddle outwards [n = 5]	0.51 [0.04]	45 [7]	0.14 [0.04]	0.26 [0.09]	0.74 [0.1]	0.07 [0.06]
Straddle inwards [n = 5]	0.45 [0.09]	54 [5]	0.17 [0.14]	0.15 [0.03]	0.80 [0.13]	0.14 [0.14]
Piked inwards [n = 1]	0.50	56.3	0.15	0.05	0.80	0.15
	L (kg·m^2/s)	L_n (SS/s)	ω (rad/s)	I_{cm} (kg·m^2)	Vy (m/s)	Vz (m/s)
Straddle outwards [n = 5]	-6.37 [1.69]	-0.21 [0.09]	-1.18 [0.42]	5.64 [1.11]	-1.86 [0.11]	1.61 [0.28]
Straddle inwards [n = 5]	-11.11 [1.88]	-0.32 [0.06]	-2.05 [0.40]	5.50 [0.89]	-2.03 [0.19]	1.72 [0.70]
Piked inwards [n = 1]	-13.71	-0.23	-1.71	8.02	-2.32	1.62

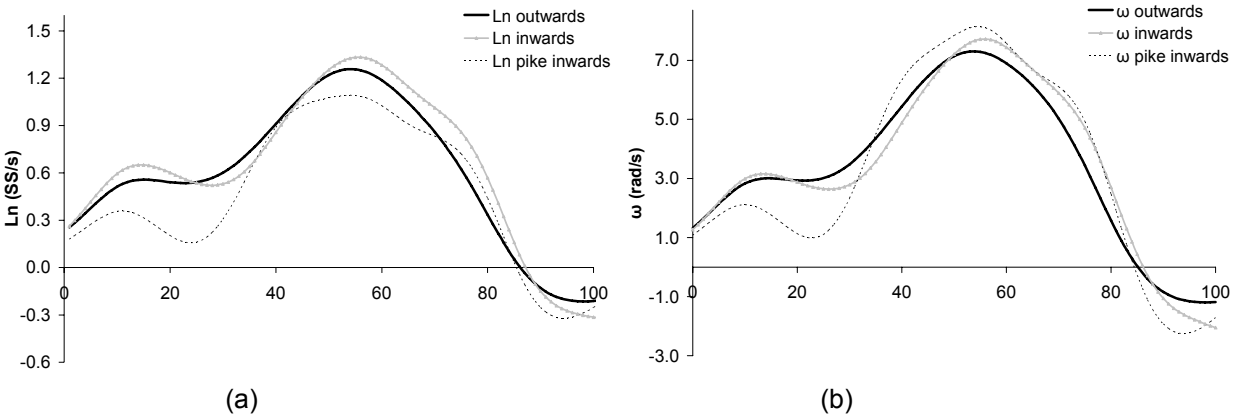

Figure 1: Mean profiles for (a) normalised angular momentum (Ln) about the mass centre, and (b) angular velocity (ω), during three variations of the Tkachev

The kinematic values at release, Vz and θ_{cm} in particular, explain the increases in peak height of the CM during flight in the inward compared to the outward Tkachevs. Comparison of the angles of release (θ_{cm}) indicates that when performing the newer style Tkachev gymnasts have longer to reverse the angular momentum and hence increase ω (Fig 1). The gymnasts' release characteristics showed that during the older style (O) Tkachevs their flight paths were flatter compared to the newer style (I).

CONCLUSION:

The presence of the lower bar clearly presents a challenge to the performance of uneven parallel bar routines. This study highlights that the direction in which gymnasts perform skills on the upper bar greatly affects their kinetics and kinematics at release. The performance of the newer style straddle Tkachev (I) enables gymnasts to develop more angular momentum than when performing the Tkachev in the conventional manner. It also enables gymnasts to release the bar with greater vertical velocity producing a steeper trajectory, resulting in increased bar clearance. Changing the direction of swing has also presented female gymnasts with the opportunity to perform piked Tkachevs and could possibly even lead to the performance of straight Tkachevs in the future. The increased height obtained by the CM also provides the gymnasts with the opportunity to re-grasp the bar earlier, increasing the potential for the skill to be immediately followed by another demanding skill.

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Acknowledgements
The authors would like to thank the IOC Medical Commission for their support during the data collection and also the colleagues at Loughborough University for their assistance with the collection of the video data.